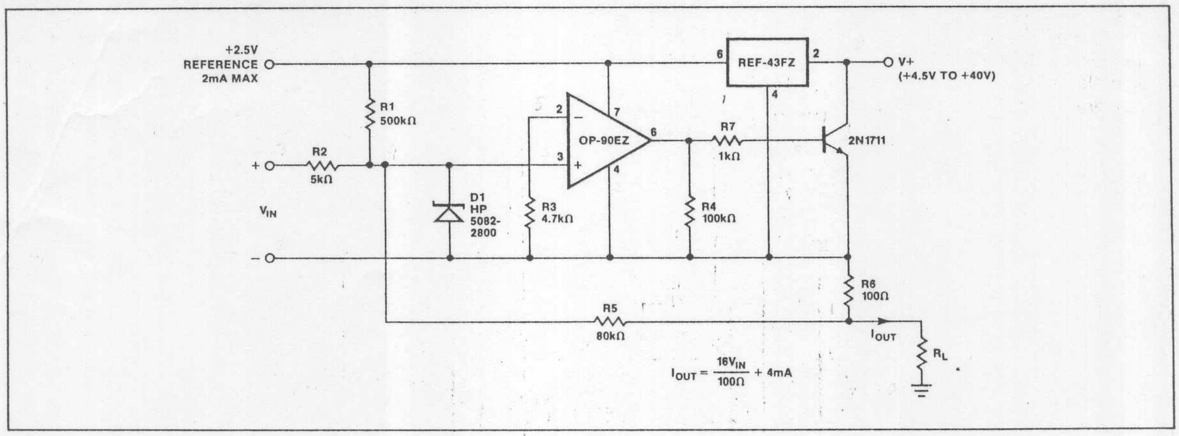
FIGURE 10: Two Wire 4-20mA Transmitter



The current transmitter of Figure 10 provides an output of 4mA to 20mA that is linearly proportional to the input voltage. Linearity of the transmitter exceeds 0.004% and line rejection is below measurement limits.

Biasing for the current transmitter is provided by the REF-43FZ. The OP-90EZ regulates the output current to satisfy the current summation at the noninverting node:

$$I_{OUT} = \frac{1}{R6}\left(\frac{V_{IN}\,R5}{R2} + \frac{2.5V\,R5}{R1}\right)$$

For the values shown in Figure 10,

$$I_{OUT} = \left(\frac{16}{100\Omega}\right)V_{IN} + 4mA$$

giving a full-scale output of 20mA with a 100mV input. Adjustment of R2 will provide an offset trim and adjustment of R1 will provide a gain trim. These trims do not interact since the noninverting input of the OP-90 is at virtual ground. The Schottky diode, D1, prevents input voltage spikes from pulling the noninverting input more than 300mV below the inverting input. Without the diode, such spikes could cause phase reversal of the OP-90 and possible latch-up of the transmitter. Compliance of this circuit is from 4.5V to 40V. The voltage reference output can provide up to 2mA for transducer excitation.

The OP-90 is also available in dual and quad versions. Using an OP-490, three of the amplifiers can be used to implement a full instrumentation amplifier for signal conditioning before delivery to the 4-20mA transmitter. All four OP-90s require less than 80μA supply current, and thus have virtually no impact on the current-budget of the 4-20mA loop.

A simple temperature to 4-20mA transmitter is shown in Figure 11. After calibration, the transmitter is accurate to within 1°C over the −50°C to +150°C temperature range. The transmitter operates from +6V to +40V with supply rejection better than 3ppm/V. An OP-90 is used to buffer the TEMP pin, while the second OP-90 regulates the output current to satisfy the current summation at its noninverting input.

$$I_{OUT} = \frac{V_{TEMP}\,(R_6 + R_7)}{R_2\,R_{10}} - V_{SET}\left(\frac{R_2 + R_6 + R_7}{R_2\,R_{10}}\right)$$

The change in output current with temperature is the derivative of the transfer function:

$$\frac{\Delta I_{OUT}}{\Delta T} = \frac{\frac{\Delta V_{TEMP}}{\Delta T}\,(R_6 + R_7)}{R_2\,R_{10}}$$

From the formulas, it can be seen that if the gain trim is adjusted before the final offset trim, the two trims are not interactive, which greatly simplifies the calibration procedure.

To calibrate the transmitter, begin by placing the REF-43 in an ice water (0°C) bath. If necessary, adjust the offset trim, R5, so that the output current is above 4mA.

Record the output current. Next, place the REF-02 in a boiling water (100°C) bath. Adjust the gain trim, R6, so that the change in the output current reflects the desired mA/°C ratio described as follows:

$$\text{Output Ratio} = \frac{\Delta I_{FS}}{\Delta T_{OPERATING}} = \frac{16mA}{\Delta T_{OPERATING}}$$

As an example, assume the transmitter is to operate over the −50°C to +150°C temperature range:

$$\text{Output Ratio} = \frac{16mA}{(150°C - 50°C)} = \frac{16mA}{(200°C)} = 0.08mA/°C$$

If I_{OUT} in the ice water bath equaled 6.3mA, then in the boiling water bath:

$$I_{OUT(100°C)} = I_{OUT(0°C)} + 100°C\ (0.08mA/°C)$$
$$= 6.3mA + 8mA = 14.3mA$$